Ozone Injury to Forest Plants

Air pollution can have noteworthy cumulative impacts on forested ecosystems by affecting regeneration, productivity, and species composition (U.S. EPA, 2013). In the U.S., ozone in the lower atmosphere is one of the pollutants of primary concern. Ozone injury to forest plants can be diagnosed by examination of plant leaves. Foliar injury is usually the first visible sign of injury to plants from ozone exposure and indicates impaired physiological processes in the leaves (Grulke, 2003).

This indicator is based on data from the U.S. Department of Agriculture (USDA) Forest Service Forest Inventory and Analysis (FIA) program, which examines foliar injury to ozone-sensitive plant species at ground monitoring sites in forest land across the country. For this indicator, forest land does not include woodlots and urban trees. Sites are selected using a systematic sampling grid, based on a global sampling design (Smith et al., 2008). At each site that has at least 30 individual plants of at least three ozone-sensitive species and enough open space to ensure that sensitive plants are not protected from exposure by the forest canopy, FIA looks for symptoms attributed to ozone on the foliage of ozone-sensitive forest plant species. Because ozone injury is cumulative over the course of the growing season, examinations are conducted in July and August, when ozone injury is typically highest.

Ozone injury to foliage is classified using a subjective five-category biosite index based on expert opinion, but designed to be equivalent from site to site. Ranges of biosite values translate to no injury, low or moderate foliar injury (visible foliar injury to highly sensitive or moderately sensitive plants, respectively), and high or severe foliar injury, which would be expected to result in tree-level or ecosystem-level responses, respectively (Smith et al., 2008).

The USDA Forest Service began monitoring ozone injury to plants in 10 states in 1994; during the ensuing decade, the program gradually expanded to cover most of the country. This indicator presents averages of all observations collected in 2006, based on 915 monitoring sites in 37 states. The results have been grouped by EPA Region in Exhibit 1. Although some data are available for more recent years, the monitoring program is currently limited to a smaller number of states as a result of funding constraints. Thus, this indicator focuses on data from 2006.

What the Data Show

There is considerable regional variation in ozone injury to sensitive plants (Exhibit 1). The highest percentages of observed high and severe foliar injury, which are most likely to be associated with tree or ecosystem-level responses, are primarily found in the Pacific Southwest, Mid-Atlantic, and Northeast. In EPA Region 9, 15 percent of ozone-sensitive plants showed signs of high or severe foliar injury. In Regions 1, 2 and 3, the proportion of sites with high or severe injury ranged from 4 to 7 percent. The percentage of sites showing no injury was greater than 50 percent in all but EPA Region 1, and no ozone-related foliar injury was observed at any of the 119 biosites in EPA Regions 6, 8, and 10.

Limitations

- Field and laboratory studies were reviewed to identify the forest plant species in each region

that are highly sensitive to ozone air pollution. Other forest plant species, or even genetic variants of the same species, may not be harmed at ozone levels that cause effects on the selected ozone-sensitive species.

- Because species distributions vary regionally, different ozone-sensitive plant species were examined in different parts of the country. These target species could vary with respect to ozone sensitivity, which might account for some of the apparent differences in ozone injury among EPA Regions.
- Ozone injury to foliage is considerably reduced under conditions of low soil moisture (Smith et al., 2003).
- Ozone may have other adverse impacts on plants (e.g., reduced productivity) that do not show signs of visible foliar injury. Conversely, the presence of ozone symptoms or injury does not necessarily mean that sensitive vegetation is suffering from damage such as reduced productivity (U.S. EPA, 2013).
- Though FIA has extensive spatial coverage based on a robust sample design, not all forested areas in the U.S. are monitored for ozone injury.
- Even though the biosite data have been collected over multiple years, most biosites were not monitored over the entire period. Thus, Exhibit 1 does not show trends over time. The USDA Forest Service has produced multi-year maps to provide an indication of patterns over time and space, but not all states have sufficient data to support a complete national map or to support year-to-year comparisons.

Data Sources

Data were provided by the USDA Forest Service's Ozone Biomonitoring Program, which maintains a database of plant injury statistics by state (USDA Forest Service, 2009) (http://www.nrs.fs.fed.us/fia/topics/ozone/data/). This indicator aggregates the state data by EPA Region.

References

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Smith, G.C., J.W. Coulston, and B.M. O'Connell. 2008. Ozone bioindicators and forest health: A guide to the evaluation, analysis, and interpretation of the ozone injury data in the Forest Inventory and Analysis program. Gen. Tech. Rep. NRS-34. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. www.nrs.fs.fed.us/pubs/gtr/gtr_nrs34.pdf (PDF) (106 pp, 8.4MB).

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USDA Forest Service (United States Department of Agriculture Forest Service). 2009. Ozone bioindicator data. Accessed 2009. http://nrs.fs.fed.us/fia/topics/ozone/data/.

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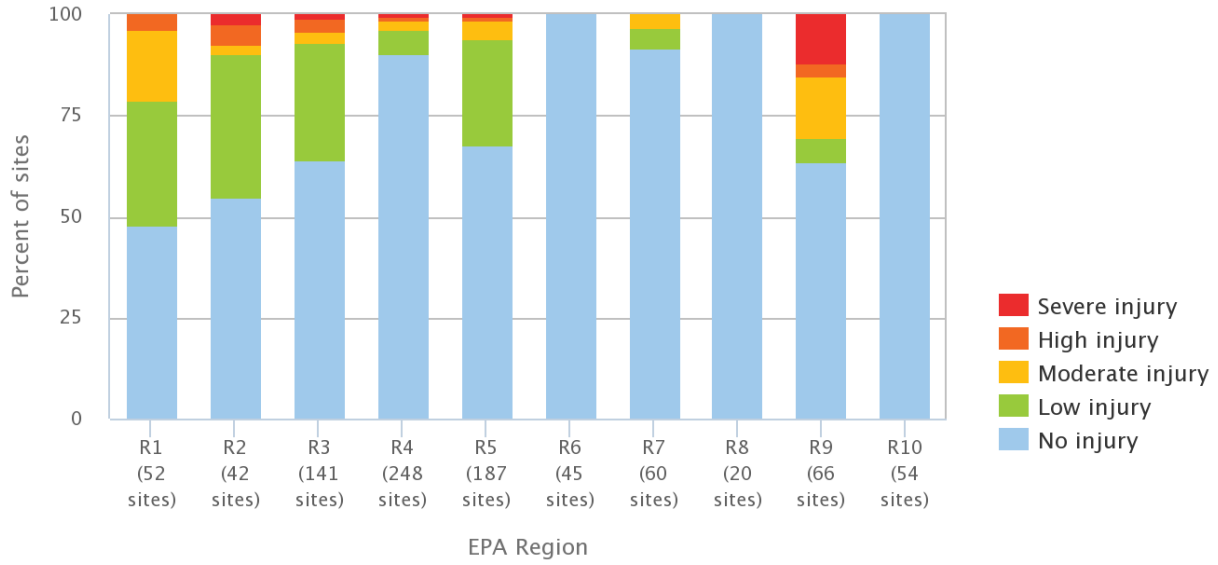
Exhibit 1. Ozone injury to forest plants in the U.S. by EPA Region, 2006



Coverage: 915 monitoring sites, located in 37 states.

Trend analysis has not been conducted because these data represent a single snapshot in time. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: USDA Forest Service, 2009